

A COST ESTIMATE FOR THE NAL 100 GEV
INTERSECTING STORAGE RINGS USING SUPERCONDUCTING MAGNETS -
A COMPARISON BETWEEN 50kG AND 60kG MACHINES

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Expected Characteristics of Improved Nb-Ti Conductors

Adiabatically stable - strand size of the order of 0.001 inches - twisted in a high resistivity substrate. Substrate to superconductor ratio 1. The material will probably be less expensive per ampere meter than today's Nb-Ti materials. (I am assuming it is the same price.) The average coil current density should be at least double that of today's Nb-Ti (Supercon T48B) with a 3 to 1 copper to superconductor ratio. Characteristics of Nb-Ti material now available and Nb-Ti that will be available in 2 years.

Coil pole field (kG)	Assumed peak coil field (kG)	1968 Material Supercon T48B		1970 Material	
		Coil current density (A/cm ²)	Cost (\$/Am)	Coil Current density (A/cm ²)	Cost (\$/Am)
25	30	3.67×10^4	2.18×10^{-3}	7.34×10^4	2.18×10^{-3}
30	36	3.14×10^4	2.55×10^{-3}	6.28×10^4	2.55×10^{-3}
35	42	2.68×10^4	2.98×10^{-3}	5.36×10^4	2.98×10^{-3}
40	48	2.30×10^4	3.48×10^{-3}	4.60×10^4	3.48×10^{-3}
45	54	1.96×10^4	4.07×10^{-3}	3.92×10^4	4.07×10^{-3}
50	60	1.68×10^4	4.76×10^{-3}	3.36×10^4	4.76×10^{-3}
55	66	1.44×10^4	5.56×10^{-3}	2.88×10^4	5.56×10^{-3}
60	72	1.23×10^4	6.50×10^{-3}	2.46×10^4	6.50×10^{-3}

A Cost Estimate for the Magnet, Cryostat, and Refrigeration
for the NAL 100 GeV Intersecting Storage Rings. A Comparison
Between 50 kG and 60 kG Machines.

A. 50 kG and 60 kG Machine Characteristics.

	50 kG Machine	60 kG Machine
Machine energy	100 GeV	100 GeV
Machine average radius	189 m	157 m
Machine magnetic radius	67.3 m	56.1 m
Magnet half aperture	10.0 cm	10.0 cm
Number of interaction sections	6	6
Length of straight sections	91.2 m	76 m
Length of interaction sections	30 m	25 m
Tunnel length	1183 m	984 m

B. Magnet Characteristics and Costs.

Inner coil radius	6.0 cm	6.0 cm
Material	1970 Nb-Ti	1968 Nb-Ti
Shielding and return path	Iron	Air
Dipole field	50 kG	60 kG
Quadrupole strength	625 kG/m	750 kG/m
Cell dipole cost	10.58 M\$	23.48 M\$
Achromatization section dipole cost	6.96 M\$	15.50 M\$
Total Dipole cost	17.54 M\$	38.98 M\$

B. Magnet Characteristics and Costs - Continued

Cell quadrupole cost	0.44 M\$	0.58 M\$
Achromatization section quadrupole cost	0.10 M\$	0.14 M\$
Low beta section quadrupole cost	0.80 M\$	1.03 M\$
Total quadrupole cost	1.34 M\$	1.65 M\$
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Correction magnet cost	1.89 M\$	4.07 M\$
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TOTAL MAGNET COST	20.77 M\$	44.70 M\$
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There is a substantial difference in the magnet cost for the two systems. Over half of the cost difference is due to a reduction in field from 60 kG to 50 kG. The above table should show why I favor the lower field machine from an economic standpoint.

C. Cryostat Characteristics and Costs.

	50 kG machine	60 kG machine
Length of cryostat	1635 m	1350 m
Number of cryostats	672	528*
Number of lead stations	6	6
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CRYOSTAT COST	6.49 M\$	5.09 M\$
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*Increased from the 432 figure which was in error.

D. Refrigeration System Characteristics and Cost.

	50 kG machine	60 kG machine
Heat leak into system	4850 watts	4235 watts
Beam heating and ac loss	1270 watts	1310 watts
Total capacity required	6130 watts	5545 watts
Number of refrigerators	6	6
Refrigerator rated capacity (each one)	1540 watts	1400 watts
Refrigerator cost	3.09 M\$	2.88 M\$
Transfer line cost	0.93 M\$	0.78 M\$
TOTAL REFRIGERATION SYSTEM COST	4.02 M\$	3.66 M\$

E. Total Machine Cost Estimate Based on LRL Numbers.

Subsystem	50 kG Iron Magnet Machine Cost	60 kG Air Core Magnet Machine Cost
Magnets	20.8 M\$	54.3 M\$**
Power Supply	1.5 M\$	2.1 M\$
Cryostats	4.5 M\$	5.0 M\$*
Refrigeration System	4.0 M\$	3.7 M\$
rf System	0.2 M\$	0.2 M\$
Injection-extraction System	1.4 M\$	1.4 M\$
Vacuum System	2.2 M\$	1.8 M\$

E. Total Machine Cost Estimate Based on LRL Numbers.
Continued -

Control System	3.3 M\$	6.6 M\$
Tunnel and plant	17.3 M\$	14.4 M\$
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SUBTOTAL Cost	55.2 M\$	89.5 M\$
50% EDIA and Contingency	27.7 M\$	44.8 M\$
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TOTAL COST	82.9 M\$	134.3 M\$
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*Corrected from a previously given value of 3.6 M\$ which was in error.

**Based on $R_1 = 8$ cm for the dipoles, $R_1 = 6$ cm for the quadrupoles. $R = 6$ cm results in a magnet cost of 44.7 M\$ and a total machine cost of 119.9 M\$.

A reduction in the magnetic field from 60 kG to 50 kG resulted in nearly half of the total cost reduction shown in the table above. The other half of the cost reduction results from the addition of an iron return path, a reduction of inner coil radius from 8 cm to 6 cm, and the use of a higher coil current density material. The optimum magnetic field lies somewhere between 45 and 50 kG. The use of Nb_3Sn in the quadrupoles will not increase the optimum field or save money.